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ABSTRACT

The primary purpose of this study was to determine what effect the diameter of the striking implement has on a basketball's rebound height and on the area of contact between the ball and the implement. A secondary purpose was to determine if changing the air pressure of the ball would alter the pattern established with standard pressure. A basketball was dropped repeatedly from a height of 100 inches above the floor onto one of three striking implements of different sizes located five inches above the floor. The mean rebound height and the mean area of contact produced by each striking implement and for each pressure was computed. Results indicated that (a) the diameter of the striking implement was a significant factor in how high the basketball rebounded, (b) the diameter of the striking implement was a significant factor in the size of the contact area, (c) the smaller striking implement produced the greatest rebound height and the least area of contact, and (d) there is an optimum implement diameter for the specific amount of force and the coefficients of restitution for the ball-implements used in this study. (PB)

THE EFFECT OF THE STRIKING IMPLEMENT'S DIAMETER ON A BALL'S REBOUND HEIGHT AND AREA OF CONTACT

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INTRODUCTORY STATEMENT

It is generally agreed that the major factors which determine the velocity of a struck ball are: (1) the speed of the approaching ball, (2) the mass of the ball, (3) the speed of the striking implement, (4) the mass of the striking implement, and (5) the coefficient of restitution of the ball and striking implement (Hay-2, and Wells-3). One additional factor which Hay (2) presents is the angle of incidence formed by the approaching ball and the striking implement.

During the testing of several different styles of baseball and softball bats on hit distance, the writer became curious about the role of the diameter of the bat's barrel on the velocity of a struck ball, a factor which did not appear to be included in those listed above. Could it be another factor? After an unsuccessful search of the literature and fruitless discussions with the research directors of several major bat manufacturers, the writer concluded that this was indeed an area in need of further research.

Special thanks is extended to Rick Attig who assisted in the collection of the data.

Since the completion of the testing for this study, Alexander and Holt (1) published a study in which they investigated the factors affecting the distance a punted football traversed. Although it was not the major purpose of their study, the writers found that a larger contact area between the ball and the foot helped produce greater distance. They stated that "the more of the ball that contacts the foot, the lesser its conformation to the foot and the sooner it leaves the foot" (p. 15).

PURPOSE OF THE STUDY

The primary purpose of the study was to determine what effect the diameter of the striking implement has on a basketball's rebound height and on the area of contact between the ball and the implement. A secondary purpose was to determine if changing the air pressure of the ball would alter the pattern established with standard pressure.

PROCEDURE

Three galvanized steel pipes* with inside diameters of 1, 2, and 3 inches and outside diameters of 1 3/8, 2 3/8, and 3 3/8 inches respectively were selected for the study. The striking implements were cut in eighteen inch sections and securely attached to wooden platfc-.s standardizing the top edge of each implement at five inches above the floor.

Each platform was positioned twelve inches in front of and

*Hereafter referred to as the striking implements.

parallel to a wall which was marked off in one inch increments. Heavy sandbags were placed on each end of the wooden platforms to secure their position and to reduce "give" between the platform and the floor.

A rubber basketball was prepared for the testing by glueing a small light-weight hook to it. A single filament nylon fishing line was attached to the basketball via the hook. The fishing line was passed through a small eye-hook which was inserted into the ceiling directly above the striking implement in the center of the wall and a second eye-hook which was placed in an adjacent wall six feet above the floor.

The ball was raised 100 inches above the floor or 95 inches above the top edge of the implement when the investigator pulled the string until a mark on it was parallel to a mark on the wall. A pole 95 inches long was used to periodically check this distance between the ball and the striking implement.

With the ball at the proper height, an assistant steadied it and aligned the trademark with a specific target. It was found that if the ball had the slightest spin or sway, that it did not rebound vertically, necessitating a retrial. After the ball was motionless, the string was released permitting the ball to fall onto the striking implement. The ball hit with its seams perpendicular to the striking implement.

An observer, located a perpendicular distance of twelve feet from the wall, noted the height of the rebound to the nearest inch. The observer assumed a position with his eyes on the same level as the bottom of the ball at the peak of its rebound which was determined by using the average rebound height of several practice trials. For those rebound heights where the observer could not assume a sitting position and brace his head with his arm, a pole with the average height of several practice trials marked off on it was used to align the eyes at the proper level. Preliminary to the study, thirty trials were given to determine the objectivity of the scoring system. The means for the two scores was 47.00 and 47.18 with standard deviations of .87 and .83 respectively. The correlation between the two scores was .87.

Twenty-five trials were given with each of the three diameters of striking implements using three different ball pressures. First, the testing was conducted with the ball at what would be considered regulation pressure; second, with the pressure reduced; and third, with the pressure increased. The ball's pressure for these three conditions was eight, five, and eleven pounds respectively and the ball's coefficient of restitution when dropped 100 inches onto a concrete floor was .72, .63, and .82 respectively. During the final ten trials for each condition (implement diameter and ball pressure), paper was taped to the implement and the bottom of the ball covered with blue tinting paint. When the ball was dropped, a permanent visual outline was obtained for the last ten trials with each implement and for all three ball pressures. To determine the area of contact between the ball and the implement, an electronic planimeter was used to measure these visual outlines.

Because of possible differences in the ball's responsiveness over the test period, only five trials were given at a time with one specific striking implement. The order of the striking implements tested was randomly determined after every round of five trials with each implement.

In dropping the ball onto the striking implement, there were times when a retrial had to be given because the ball did not rebound vertically from the implement. Since the implements were positioned parallel to the wall, the ball either rebounded toward or away from the wall when a mistrial had to be declared. To insure that only those balls which rebounded vertically were counted, both the assistant who released the ball and the assistant on the ladder who steadied the ball served as judges. Any ball judged to have rebounded too far from vertical (6 inches from a perpendicular line to the inside edge of the ball) was declared a mistrial. There were 149, 89, and 96 mistrials with the 1, 2, and 3 inch implements respectively.

RESULTS OF THE STUDY

The mean rebound height and the mean area of contact produced by each striking implement and for each ball pressure was computed. These results, as well as the standard deviations and the ranges, are presented below in Tables 1 and 2.

An analysis of variance for independent groups was computed to determine if the three diameters of striking implements produced any significant differences in the height of rebound and the area of contact. These results are presented below in Tables 3-14. A significant F was found in each case and the Tukey method for comparing all pairs of means was employed to compare one diameter with another. All differences between the striking implements were found to be significant at the .01 level of confidence.

Table 1

Means and Standard Deviations for Rebound Height*

	1" Implement			2" Implement			3" Implement		
Air Pressure	$\overline{X}$	SD	Range	$\overline{X}$	SD	Range	$\overline{X}$	SD	Range
Reduced	64.44	1.04	4.00	61.48	1.05	4.00	58.04	.79	3.00
Regular	72.84	.85	2.00	70.32	.56	2.00	68.40	.58	2.00
Increased	79.44	.71	2.00	78.24	.53	2.00	77.44	.71	2.00

*In Inches

Table 2

Means and Standard Deviations for Area of Contact*

	1" Implement			2" Implement			3" Implement		
Air Pressure	$\overline{X}$	SD	Range	$\overline{X}$	SD	Range	$\overline{X}$	SD	Range
Reduced	9.99	.10	.29	15.08	.13	.39	17.88	.30	.90
Regular	7.32	.08	.20	11.03	.16	.46	13.48	.20	.51
Increased	5.48	.13	.34	8.29	.09	.28	10.36	.16	.59

*In Square Inches

Figure 1

MEAN REBOUND HEIGHTS

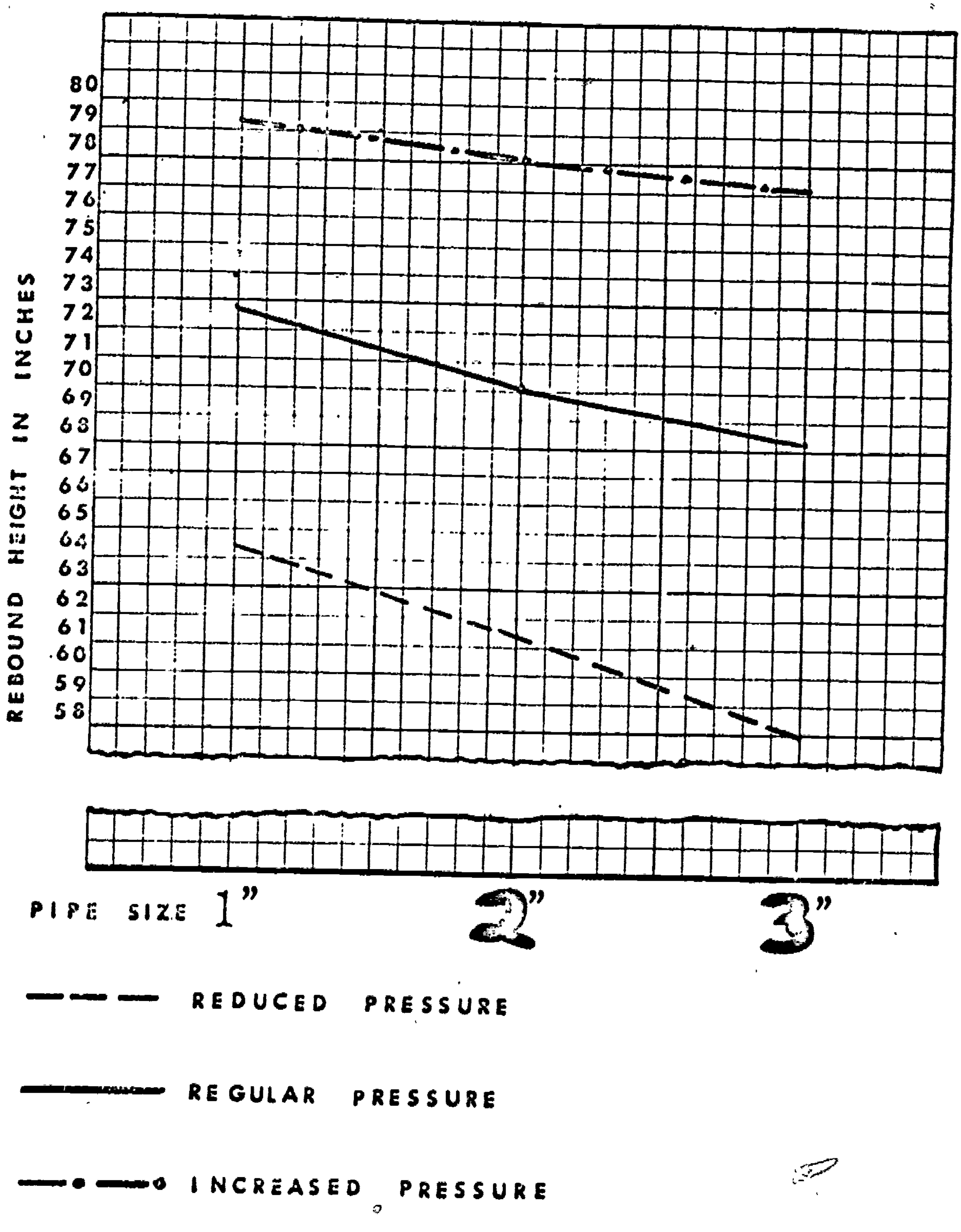

Figure 2

MEAN AREA OF CONTACT

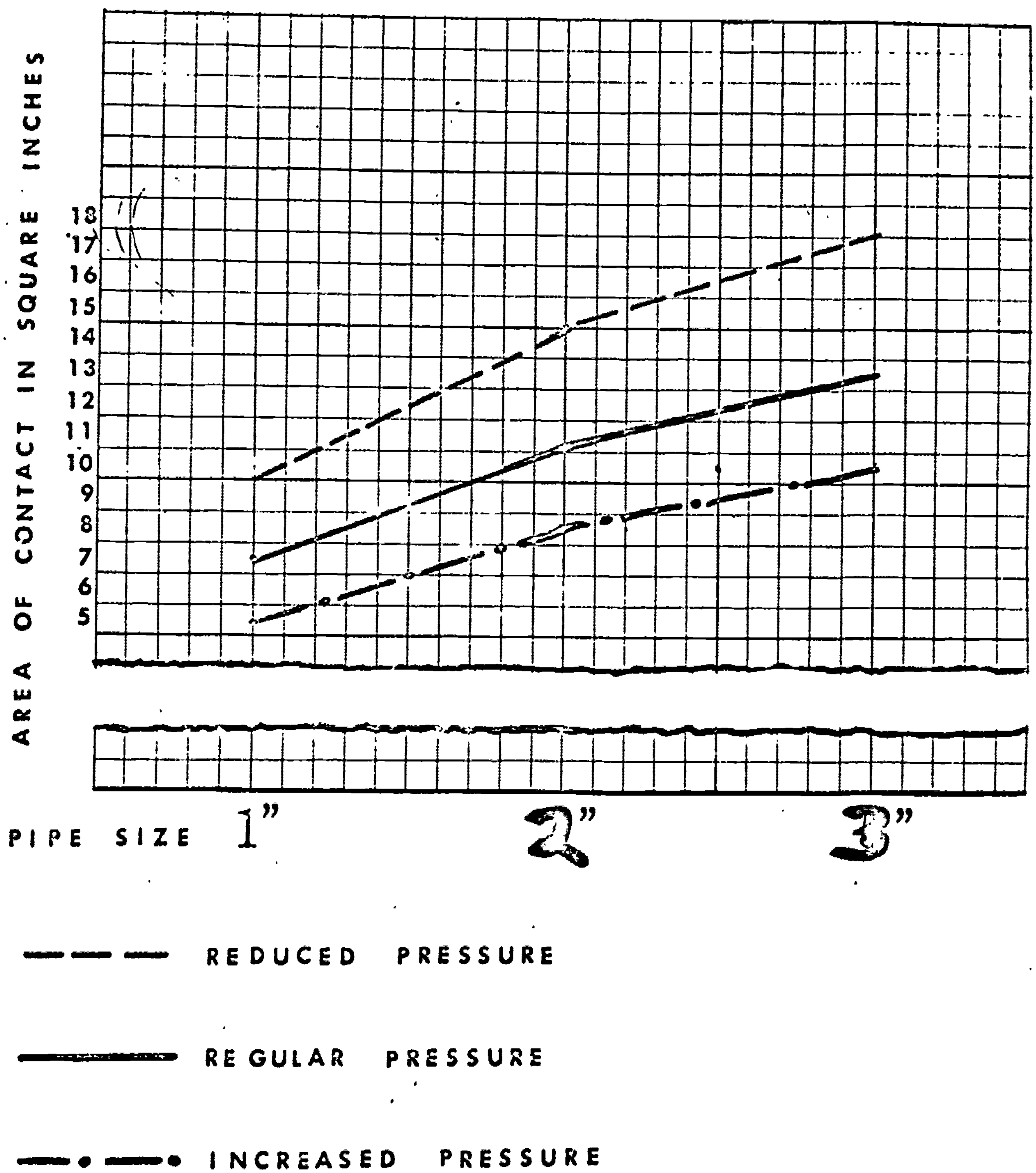

Table 3

Analysis of Variance for Rebound Height of Ball with Reduced Air Pressure

Variation	DF	SS	F
Between	2	512.94	273.82*
Within	72	67.44	
Totals	74	580.38	

*Significant at .01 level

Table 4

Differences Between Sample Means for Rebound Height and Reduced Pressure

Comparison of Means	Comparison Mean	Smallest Mean	Comparison Mean	Second Smallest Mean
64.44	64.44	- 58.04=6.40*	64.44	-61.48=2.96*
61.48	61.48	- 58.04=3.44*		
58.04				

T = .83 *Significant at .01 level

Table 5

Analysis of Variance for Rebound Height of Ball with Regular Air Pressure

Variation	DF	SS	F
Between	2	247.88	271.44*
Within	72	32.88	
Totals	74	280.75	

*Significant at .01 level

Table 6

Differences Between Sample Means for Rebound Height and Regular Pressure

Comparison of Means	Comparison Mean - Smallest Mean	Comparison Mean - Second Smallest Mean
72.84	72.84-68.40 = 4.44*	72.84 - 70.32= 2.52*
70.32	70.32-68.40 = 1.92*	
68.40		

T = .58 *Significant at .01 level

Table 7

Analysis of Variance for Rebound Height of Ball with Increased Air Pressure

Variation	DF	SS	F
Between	2	50.69	58.98*
Within	72	30.94	
Totals	74	81.63	

*Significant at .01 level

Table 8

Differences Between Sample Means for Rebound Height and Increased Pressure

Comparison of Means	Comparison Mean - Smallest Mean	Comparison Mean - Second Smallest Mean
79.44	79.44 - 77.44 = 2.00*	79.44 - 78.24 = 1.20*
78.24	78.24 - 77.44 = .80*	
77.44		

T = .56 *Significant at .01 level

Table 9

Analysis of Variance for Area of Contact for Ball with Reduced Air Pressure

Variation	DF	SS	F
Between	2	320.09	4266.05*
Within	27	1.01	
Totals	29	321.10	

*Significant at .01 level

Table 10

Differences Between Sample Means for Area of Contact and Reduced Pressure

Comparison of Means	Comparison Mean - Smallest Mean	Comparison Mean - Second Smallest Mean
17.88	17.88 - 9.99 = 7.89*	17.88 - 15.08 = 2.80*
15.08	15.08 - 9.99 = 5.09*	
9.99		

T = .28 *Significant at .01 level

Table 11

Analysis of Variance for Area of Contact for
Ball with Regular Air Pressure

Variation	DF	SS	F
Between	2	192.30	4171.66*
Within	27	0.62	
Totals	29	192.92	

*Significant at .01 level

Table 12

Differences Between Sample Means for Area of
Contact at Regular Pressure

Comparison of Means	Comparison_Smallest Mean Mean	Comparison_Second Mean Smallest Mean
13.48	13.48 - 7.32 = 6.16*	13.48 - 11.03 = 2.45*
11.03	11.03 - 7.32 = 3.71*	
7.32		

T = .22 *Significant at .01 level

Table 13

Analysis of Variance for Area of Contact for
Ball with Increased Air Pressure

Variation	DF	SS	F
Between	2	120.04	3543.91*
Within	27	0.46	
Totals	29	120.50	

*Significant at .01 level.

Table 14

Differences Between Sample Means for Area of Contact and Increased Pressure

Comparison of Means	Comparison Mean	Smallest Mean	Comparison Mean	Second Smallest Mean
10.36	10.36 - 5.48 = 4.88*		10.36 - 8.29 = 2.07*	
8.29	8.29 - 5.48 = 2.81*			
5.48				

T = .19 *Significant at .01 level

Table 15

Correlation Between Area of Contact and Rebound Height*

	Area**		Rebound Height***		
Pressure	Mean	SD	Mean	SD	r
Reduced	14.31	3.27	62.13	2.88	-.93
Regular	10.61	2.54	71.17	2.00	-.97
Increased	8.05	2.00	78.50	1.28	-.87

*Last 10 trials with each diameter
**In Square Inches ***In Inches

Table 16

Relationship Between Odd-Even Trials for Regular Pressure*

Implement	$\overline{X}$*		SD*		r	Spearman Brown
	Odd	Even	Odd	Even		
1"	72.750	72.917	.866	.902	.67	.80
2"	70.333	70.333	.653	.497	.76	.86
3"	68.333	68.417	.493	.672	.92	.96

*In Inches

DISCUSSION

The results indicate that the diameter of the striking implement is a factor in the height the ball rebounded. Based on the finding that the area of contact was the greatest between the ball and the striking implement with the largest diameter and that the height of rebound was the lowest with the largest diameter, the investigator would hypothesize that it is the ball-pipe coefficient of restitution which is responsible for the differences in rebound height. It appears that as the area of contact increases, the efficiency of the collision decreases with a greater proportion of the energy being lost in the form of heat and sound. In addition, the implement with the smallest diameter enables a greater percentage of its force to be directed through the ball's center of gravity while the two implements with larger diameters not only cause the force to be directed through a greater area, but they absorb it over a greater area as well.

An interesting sidelight to this study was that the ball rebounded several inches higher during the last ten trials with each implement when the tinting paint was on the ball and the paper taped to the striking implements. Although the investigator cannot explain its occurrance, the fact that such a change in the colliding surfaces could alter the rebound height so noticably leads the investigator to believe that the results of this study should definitely not be generalized without testing the specific collision of interest.

CONCLUSIONS

Based on the results of this study, it appears justified to conclude that:

1. The diameter of the striking implement was a significant factor in how high the basketball rebounded.

2. The diameter of the striking implement was a significant factor in the size of the contact area.

3. The smaller striking implement produced the greatest rebound height and the least area of contact.

4. There is an optimum implement diameter for the specific amount of force and the coefficients of restitution for the ball-implements used in this study.

IMPLICATIONS

Recognizing that the above results might hold true for only the particular ball, striking implements, force applied, and coefficient of restitutions tested in this study, it would seem warranted to investigate the effect of utilizing:

1. Softball and baseball bats which have smaller barrel diameters. Thinner bat barrels might be more appropriate for slow-pitch softball where contact is not a major problem.

2. A kicking shoe which would bring a smaller surface area into contact with the football. This would especially be true for kick-offs where the needed accuracy is not great.

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